Homing Behavior of Tagged and Displaced Carp, *Cyprinus carpio,* in Pymatuning Lake, Pennsylvania/Ohio[1]

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ABSTRACT. Pymatuning Lake, located on the Pennsylvania/Ohio border, is noted for the large numbers of bread-eating carp that frequent the Linesville Causeway "carp bowl" from May to November. Carp were trapped in 1952 and 1984 at the carp bowl, tagged, and relocated varying distances away from the bowl in Sanctuary, Middle, and Lower lakes. Carp traversed the return distances of up to 9 km in less than 4 or 5 days. Return movements often necessitated swimming around Tuttle Point and across the length of Middle Lake. One carp did migrate northward in 1984, but not 1952, from Lower Lake through the east-west Andover-Espyville Causeway into Middle Lake. Another carp released near the bowl in Middle Lake in 1984 migrated west and south through the Andover-Espyville Causeway and was caught 23 km to the west and south near the Lower Lake dam at Jamestown, Pennsylvania. Larger and older carp frequented Sanctuary and Middle lakes. Carp sizes decreased progressively with distance from the bowl. Visual cues, currents, sounds, sun orientation, "follow-the-leader", and schooling behavior did not explain the carp aggregations in the carp bowl or the homing behavior by carp. Odors from feeding carp or other sources may be the causal basis for the homing behavior.

OHIO J. SCI. 87 (1): 15-22, 1987

INTRODUCTION

Many freshwater fishes exhibit homing or specific migratory behaviors (McCleave et al. 1982). Examples include salmon which travel great distances from freshwater to the sea and return to their native stream to breed (Hasler and Scholz 1983) and the carp, *Cyprinus carpio*. Johnson and Hasler (1977) used ultrasonic tracking gear to document winter aggregations of carp in Lake Mendota, Wisconsin. Similar techniques were used by Otis and Weber (1982) and Priegel (1982) to record carp movements in Lake Winnebago and several other Wisconsin lakes. Osipova (1979) described specific movements of wild carp in the Cheremshansk pool of the Keybyshev Reservoir in Russia. Vostradovska (1975) and Vostradovsky (1974) noted the movements of carp in Lipno Reservoir, Czechoslovakia. Yet, with the natural and worldwide occurrence and introduction of carp, its ability to home or aggregate has been overlooked.

Since the creation of Pymatuning Lake, myriads of carp congregate annually at its Linesville Causeway "carp bowl" to feed on bread tossed to them from May to November by tourists. This study, which was done during the summers of 1952 and 1984, was designed to address the following questions. (1) Why do carp congregate at the Linesville Causeway carp bowl? (2) Is their behavior innate or a learned response? (3) Are they drawn to the carp bowl by the abundance and availability of food? (4) If displaced to other parts of the lake do they return to the bowl? (5) At what speed, and by what avenues do they return, and is the aggregating behavior the same over time?

[1]Manuscript received 28 March 1986 and in revised form 8 August 1986 (#86-20).

STUDY AREA. Pymatuning Lake is a 24-km-long, L-shaped impoundment on the Pennsylvania-Ohio state line, that is divided into three parts by two causeways. Construction of the lake began on 5 December 1933; the dam at Jamestown, Pennsylvania was closed on 1 January 1937.

Sanctuary Lake (Fig. 1), the east-west part of Pymatuning Lake, is formed by the north-south Linesville Causeway located at its western edge. Overflow water from Sanctuary Lake passes into the "carp bowl" and Middle Lake. Middle Lake extends from the Linesville Causeway northwest and then southward 9.6 km to the east-west Andover, Ohio-Espyville, Pennsylvania Causeway. Two small openings in this causeway connect Middle Lake waters with those in the longer Lower Lake, which is dammed at Jamestown, Pennsylvania, located 14 km to the south. The maximum width of Pymatuning Lake is 3.5 km, with most widths averaging 2.5 km. The average depths of Sanctuary, Middle, and Lower lakes are 2.4, 3.0, and 4.0 m, respectively. Water depth near the carp bowl is about 5.3 m. Maximum depths of 11.4 m are known in the Lower Lake near Jamestown, Pennsylvania. Water levels in Sanctuary Lake are governed by the height of the concrete Linesville Causeway. Excesses simply spill over into Middle Lake. Water levels in Middle and Lower lakes may fluctuate 2 m throughout the year, depending on discharges into Shenango River at Jamestown, Pennsylvania.

STATIONS AND HABITAT DESCRIPTIONS. The carp bowl (CB) is a semicircular, concrete-lined area about midway along the Linesville Causeway. A water level differential of 1 m usually exists between Sanctuary Lake to the east and Middle Lake to the west. Water passing from Sanctuary Lake flows over a spillway into Middle Lake. Carp congregate in Sanctuary Lake along the causeway and spillway.

Water in the bowl flows along a concrete-lined and walled discharge tailrace into Middle Lake. Pennsylvania Route 285 and an abandoned Pennsylvania Central railroad bridge also cross over the outlet of the 20-m-wide tailrace. An abandoned railroad breakwater, 60 m to the west of the carp bowl tailrace outlet, with central channel piers, protects the bowl area from violent wave actions, although extreme westerly storms do cause occasional water surges within the bowl. Middle Lake water levels at the bowl are affected by lake drawdown as well as prevailing summer winds from the west or southwest. Water depth in the carp bowl is about 5.3 m; flows vary according to seasonal overflow from Sanctuary Lake.

MS2 (Fig. 1) is a channel station located between the largest island (Soldier?) situated on the south shore of Middle Lake about 1 km east of Tuttle Point (T). Water depth at this station is 1 m. Mud and sand substrates prevail. Enormous stands of *Myriophyllum* and *Lotus* flourish during the summer months. In June, both MS1 and MS2 are used as one of the prime Middle Lake carp spawning areas. The area is protected from all but northerly winds.

All other stations (Fig. 1), MS, MN, LEO, and SS, have a water depth of 1 to 2 m, mud-sand substrates, and gradual shore slopes, and are subject to wave action from prevailing winds. Stations MS1, MS3, MN3, and MN6 are also subject to heavy *Myriophyllum* growths from May through August. Site MN2 has many stumps, logs, and fallen trees; rocks, stones, and pebbles line the substrate of MN4 and are found along the shore of MS3. Sanctuary stations (SS1 and SS2) are subject to dense summer blooms of *Microcystis* (in 1952) or *Anabaena* in July and August (in 1984).

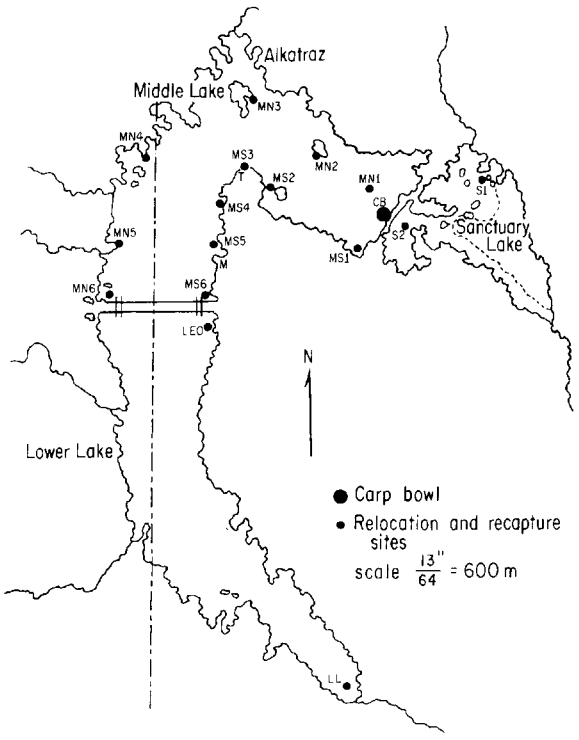

FIGURE 1. Map of Pymatuning Lake denoting carp bowl (CB), location of the three lake partitions and two causeways, and relocation sites for releases of tagged carp in 1952 and 1984. Note that fish relocated to MS4, MS5, and MS6 stations had to swim north for 4.8 km before swimming eastward to the bowl.

MATERIALS AND METHODS

The carp bowl was sampled daily during the summers (July-August) of the 1950's by the Pennsylvania Fish Commission (PFC). Carp were captured at the bowl by lifting an unbaited metal frame (20 m^2) fitted with webbing. These fish were stocked throughout the state and were also used in the 1952 studies.

Two methods were used to capture carp in 1984. A seine (21 × 1.5 m; 15 mm bar mesh) was used at all relocation stations where water depths were less than 1.5 m. Varying shoreline distances (30-150 m) were sampled at each site, depending on absence of snags or vegetation. The number of sweeps of the seine in each habitat was determined by the size of catch. A bag (1.2 × 1.2 m) was fitted into the seine in July to prevent carp from escaping the net by digging under the lead line. Seining was not attempted in August, when carp were scattered widely throughout the lakes.

Morton Big "M" traps were set at the carp bowl breakwater as well as most relocation stations. The Big "M" is a metal-framed trap (1.2 × 1.2 × 0.6 m) covered with knotless netting (38 mm bar mesh). Additional netting buoyed with floats permit its extension to a height of 1.5 m. A vertical slit on each side of the vertical webbing permits entry to the trap. Entry to a conical bait box in the center of the trap is through a flap in the bottom mesh (Schwartz 1986). Baits were either pressed soybean or cottonseed cake that had been soaked in molasses. Traps were fished for 24 h and were checked daily, usually at 0700 and 1500 h. Sampling periods in 1984 were 6-10 May, 3-9 June, 13-16 July, and 14-19 August. Standard lengths (mm, SL) were recorded for all carp captured or relocated during the 1952 and 1984 studies. Air and water temperatures (°C), wind conditions, water clarity, spawning activity, and behavior of carp were also recorded in both years.

Carp were tagged in 1952 with a colored 30-mm plastic disk tag on the operculum. The tag was fastened by drilling a 2-mm hole in the right or left operculum with a power drill. Each tag was numbered consecutively but lacked information such as return address. Solid colors were used, with each color denoting the station to which carp bowl fish were displaced during July-August, 1952.

Tagging in 1984 consisted of attaching a 12-mm colored Peterson disk tag to either the right or left operculum. A hand drill fitted with a 2-mm bit provided the hole for a monel nickel pin, crimped on the outside, to secure an outer colored and numbered disk to a colored disk on the inside of the operculum. Solid or multicolored tags were used to denote each relocation site. Each tag was numbered and carried a return address. Tags were attached to the left operculum in May, June, and August and to the right operculum in July. Fish that were recaptured several times were simply retagged (leaving the original tag in place) with additional tags depending on month, location site, color, and side of operculum.

Personnel of the PFC reported carp returns to the bowl frame trap during the 1952 study. In 1952, the public and fishermen reported sightings at the carp bowl and recaptures elsewhere to the various concessionaires located at the bowl and marinas west of Linesville, Espyville, and Jamestown, Pennsylvania or Andover, Ohio.

The same procedure was followed in 1984, except that several new boat access ramps had been constructed during the intervening years. Observations and catches from these points were monitored by state park personnel. Additional observations and tag returns were provided by creel census observers from the PFC and Ohio Department of Natural Resources (Division of Wildlife), who monitored the lakes daily during several circuits of Middle and Lower lakes. Recaptures in late October, 1984 and 1986, were obtained in PFC test gill nets set at the carp bowl breakwater. Fishermen supplied data for carp recaptured in 1985 and 1986. Posters explaining the 1984 study and need for reports of sightings or recaptures were passed out to fishermen and were posted throughout the lakes at concession stands, boat landings, and the like. Transport of carp to relocation sites in 1952 and 1984 was done primarily by boat; distant locations, such as LEO or MN6, were serviced by car. During transport, fish were kept in washtubs filled with aerated lake water.

June of 1984 was unique in that an unexpected way occurred to test whether or not local carp populations existed in Pymatuning Lake. That is, if tag returns at a site other than the carp bowl produced large numbers of recaptures, those observations would confirm that the bowl population was not the only one present in Middle Lake. The test occurred as a result of the enormous spawning of carp that took place in the slough located at MS2 (Fig. 1). During this period, 597 carp were seined rather than trapped at MS2. Relocation of MS2 fish to all but the carp bowl localities yielded only one recapture. This was a fish 597 mm in length (Table 2) that was relocated to MS3 and reseined at MS2 1.5 days later. None of the other relocated carp were recaptured at MS2 or at the bowl suggesting that MS2 at least was not a local static phenomenon. Apparently the carp (300-350 mm SL) common to MS2 during the spawning period dispersed throughout Middle Lake following spawning, rather than migrating to the carp bowl.

TABLE 1

Number of carp recaptured at the carp bowl (CB) following relocation from the bowl to several release sites in Sanctuary, Middle, and Lower lakes in 1952 and 1984.

	1952 N		1984 N	
Station*	Relocated to site from CB	Recaptured at CB	Relocated to site CB or MS2**	Recaptured at CB
SS1	0	0	3	0
SS2	0	0	2	0
MS1	150	34	313	3
MS2	120	18	155	4
MS3	190	27	82	1
MS4	220	13	134	6
MS5	180	21	150	4, M
MS6	190	38	115	1, T
LEO	100	0	74	AK
MN1	150	36	134	LL
MN2	250	20	114	5
MN3	240	17	71	5
MN4	40	23	207	5
MN5	60	7	70	2
MN6	60	3	0	0
TOTAL	1950	257	1624	36***

*See Figure 1 for site location.

**597 were seined at MS2 in June and relocated to all Middle Lake stations.

***One each was also recaptured at M = Manning (MS5), T = Tuttle Point (MS3), AK = Alkatraz, and LL = Lower Lake. See Table 2 for their original relocation sites.

RESULTS

1952. Thirteen stations located in the middle and lower portions of Pymatuning Lake received a total of 1,930 tagged and relocated carp that had been netted at the carp bowl in July and August, 1952 (Fig. 1, Table 1). Relocated carp ranged in size from 224 to 550 mm SL. Although three forms of carp (scaled, mirror, and leather) comprised the experimental fish, accurate counts of each variety used were not recorded.

Carp (N = 257, 200-550 mm SL) from 12 of the 13 relocation stations returned to the carp bowl (the only checkpoint monitored) after periods of 0.5-4 days (Table 1). Carp from MS1 returned to the bowl (0.8 km) in less than 12 h following release near the present University of Pittsburgh housing facility. Fish from MS2 took an average of one day to travel the 4.0 km back to the bowl; MS3 fish averaged two days for the return from the Tuttle Point area. The MS4 and MS5 carp took three days to return, having negotiated Middle Lake by a northerly and then easterly movement past Tuttle Point. Fish from MS6 took 4 to 4.5 days to travel the 9.6 km back to the bowl. No fish relocated in 1952 to LEO in the Lower Lake negotiated the apertures in the Andover-Espyville Causeway.

Carp released at stations MN1 and MN2 took one and two days, respectively, to return to the bowl; MN3 fish averaged 2.5 days for the return. Fish released at MN4 returned to the carp bowl in three days by swimming 6.4 km easterly across Middle Lake. This required crossing the lake before reaching the bowl. Carp relocated to MN5 and MN6 took three to five days to return, swimming northeasterly across Middle Lake prior to passing Tuttle Point.

Tagged and relocated carp from Sanctuary Lake stations 1 and 2 never returned to their site of origin, even though a wider, open-area channel existed between the two parts of the Sanctuary than in the Andover-Espyville Causeway.

1984. Thirteen stations located in Sanctuary (2), Middle (10), and Lower lakes (1) received 1,624 (1,546 scaled, 38 mirror, 40 leather) relocated, tagged carp. Returns (recaptures) consisted of fish released in Middle and Lower lakes (Fig. 1). None of the five fish tagged in Sanctuary Lake were sighted at the spillway side of the bowl or were captured in Middle Lake.

In 1984 (mainly July), fishermen accounted for 12 recaptures (Tables 2, 3A); the author's efforts accounted for 19 tagged fish. All but four of the recaptures were at the carp bowl breakwater area. Of these, one each was

TABLE 2

Tagged carp recaptured by fishermen and during this study (May, 1984–October, 1986), by month, standard length (SL), days at liberty, and distance traveled between release and capture site throughout Pymatuning Lake, Pennsylvania/Ohio. CB = carp bowl. LL = Lower Lake.

	Fishermen					Study				
Month	SL (mm)	Days at liberty	Release site	Distance traveled (km)	Recapture site	SL (mm)	Days at liberty	Release site	Distance traveled (km)	Recapture site
1984										
Jun						325	22	LEO	9.6	Alkatraz
						264	3	MS3	8.0	MS2
Jul	292	32	MS6	4.8	Tuttle Pt.	407	2	MN3	5.6	CB
	407	24	MN3	6.4	CB	318	3	MS2	4.0	CB
	318	90	MS1	1.6	CB					
	400	5	MS5	8.0	CB					
	338	86	MS4	6.4	CB					
	344	86	MS4	6.4	CB					
	243	34	MN2	2.4	CB					
	300	29	MS5	1.4	Manning					
Aug	346	30	MN2	3.2	CB	406	31	MN1	3.2	CB
	295	6	MS2	3.2	CB	300	32	MN4	6.4	CB
	301	35	MN1	1.6	CB	311	31	MS3	4.8	CB
	425	32	MS4	6.4	CB	391	35	MN1	1.6	CB
						318	4	MS2	4.0	CB
						331	33	MS2	4.0	CB
						300	4	MN3	5.6	CB
						279	25	MN2	4.0	CB
						321	4	MN2	4.0	CB
						425	4	MN4	6.4	CB
						246	32	MS5	8.0	CB
						276	33	MS5	8.0	CB
						318	3	MS4	6.4	CB
						318	26	MS4	6.4	CB
						325	27	MS4	6.4	CB
1985										
Mar	475	211	MN1	0.8	CB					
Jun	375	318	MS6	9.6	CB					
	420	345	MS5	8.0	CB					
Aug	406	383	MN3	4.8	CB					
	325	385	MN2	4.0	CB					
	410	365	MS1	1.6	CB					
	453	374	MN1	23.0	LL					
Sep	439	344	MS1	1.6	CB					
Oct	328	360	MN1	0.8	CB					
1986										
Oct	325	778	MN2	3.2	CB					
	300	777	MN4	6.4	CB					
	310	774	MS1	1.6	CB					

from Tuttle Point (T), MS2, and the Manning boat landing (M, MS5 area, Fig. 2); the fourth carp was found dead at Alkatraz.

Fishermen captured nine additional carp in 1985 and three in 1986; 11 recaptures were at the carp bowl (Table 2). The remaining recapture was the most notable, however, as it was recaptured on a sunken sandbar 374 days after its release in the Lower Lake (LL) on 23 August 1985 just west of Ackerman Island and near the Lower Lake dam. This recapture showed that carp can traverse the Andover-Espyville Causeway (Fig. 1). Prior to recapture, this fish also moved a distance of 23 km west and south from its original release site at MN1 in Middle Lake.

Little size difference was noted for recaptured carp collected by fishermen or in the present study (Table 3B). The average time at liberty was greater for carp caught by fishermen than for those retrapped during the study (Table 3C). Most fish recaptured in 1985 were at liberty 211-385 days; the range for 1986 was 774-778 days. (Table 3C).

Of the 19 study tagged carp recaptured (Table 2) in this study, only one was reseined at MS2 after release at MS3 (Fig. 1). Likewise, it appears (Table 2) that one carp bowl fish released in June at LEO in the Lower Lake did apparently negotiate the Andover-Espyville Causeway aperture as it was found dead at the Alkatraz boat ramp (Fig. 2). Whether it actually migrated to Alkatraz or was caught on its way back to the bowl by fishermen who later discarded it at Alkatraz remains unresolved. Most recaptured carp traveled distances of at least 6.4 km back to the bowl in just three days, whereas others (Table 2)

TABLE 3

Recapture of tagged carp by fishermen and during this study, Pymatuning Lake, 1984, 1985, and 1986. Data are arranged by month (A), size (B), and days at liberty (C).

(A) Recapture by month:

	1984				1985					1986	TOTAL
	May	Jun	Jul	Aug	Mar	Jun	Aug	Sep	Oct	Oct	
Fishermen	0	0	8	4	1	2	4	1	1	3	24
This Study	0	2	2	15	—	—	—	—	—	—	19

(B) Original means and ranges of standard lengths (mm) of recaptured carp:

	1984				1985					1986
	May	Jun	Jul	Aug	May	Jun	Aug	Sep	Oct	Oct
Fishermen $\bar{x}$	0	0	330	342	475	397	398	344	328	312
range			243–407	295–425	475	375–420	325–453	344	328	300–325
This Study $\bar{x}$	0	295	366	326	—	—	—	—	—	—
range		264–325	325–407	246–425						

(C) Means and ranges of days at liberty before recapture of tagged carp:

	1984				1985					1986
	May	Jun	Jul	Aug	May	Jun	Aug	Sep	Oct	Oct
Fishermen $\bar{x}$	0	0	48	26	211	311	378	344	360	776
range			5–90	6–35	211	318–345	367–385	344	360	774–778
This Study $\bar{x}$	0	3	3	21	—	—	—	—	—	—
range		2–4	2.5–3.5	1–35						

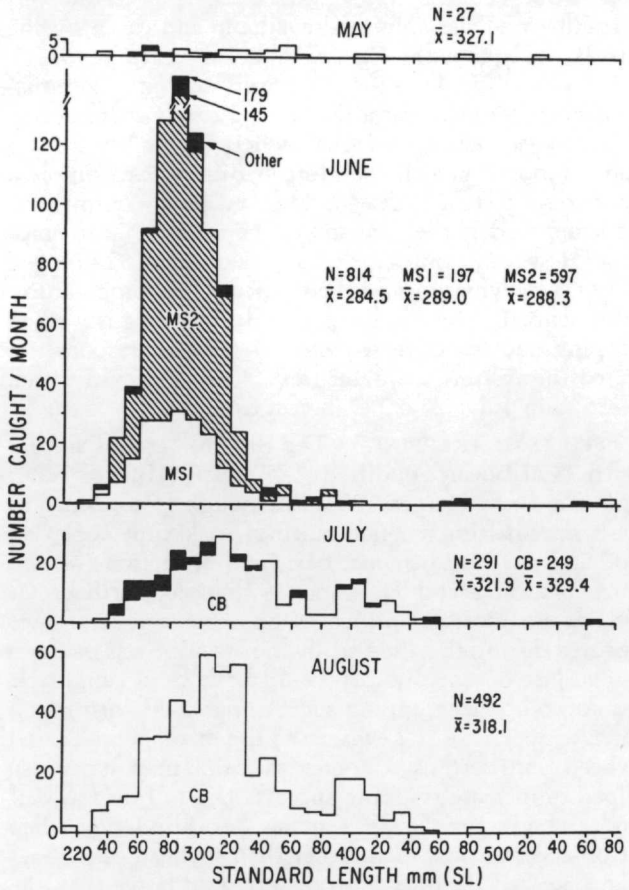

FIGURE 2. Length frequency histograms of carp captured May-August 1984. CB, MS1, and MS2 are carp from the carp bowl. "Other" category are sizes of carp seined or trapped at other relocation stations in Pymatuning Lake.

took 32 and 33 days, respectively, to swim only 1.6 km further (Table 2, Fig. 1). The majority of recaptures occurred in August rather than June or July; yet as carp were moved farther away from the bowl, the number of recaptures decreased (Table 2).

Tagged carp were recaptured in good condition by fishermen and the author (Tables 2, 3) at distances as great as 6.4 km (Middle Lake) or 23 km (Lower Lake) from the carp bowl. One fish swam the 6.4 km across Middle Lake in as little as 4 days (Table 2); others took periods of time ranging from 3 to 26 days to swim from MS5 around Tuttle Point to the bowl.

Only two fish were recaptured and retagged more than once during the 1984 study (Table 2). The first was recaptured at the carp bowl in June and relocated to MN3. It was recaptured at the carp bowl four days later. Following relocation in July to MS3, the same carp traveled (distance of 5.6 km) to the carp bowl in two days. It was released again in July at MS2. Further seining at MS2 showed that this fish exhibited no further movement in July.

A second carp, first captured in July at the carp bowl, was relocated to MS2 (Fig. 1) from which it returned to the bowl in 2.5 days (Table 2). When it was retagged and transferred to MS4, it returned in three days and was recaptured for the second time at the bowl (Table 2). A third relocation to MS4 resulted in a return to the carp bowl in 26 days (Table 2). A final relocation to MS1 was made in August.

Water temperatures were about 10°C in May 1984 and apparently made carp sluggish and hard to capture. Few fish frequented shallow areas of the lakes in May. Temperatures in June ranged from 19 to 24°C and warmed to 22 to 29°C by August. The majority of the spawning

occurred in June when water temperatures ranged from 19 to 21°C. Most recaptures occurred in July and August, when temperatures varied from 24.5 to 29°C.

Large (400-550 mm SL, ages 10-13), untrapped carp were the most abundant sizes in the carp bowl proper during the June spawning period as well as during the June-August capture period. Carp ranging from 300 to 350 mm (SL) spawned by the thousands at MS1 and especially MS2. Spawning was intense at MS2 from 1 June to 15 June (Pennsylvania Fish Commission, pers. comm.). Catches of carp at the carp bowl in 1984 increased from 0 in May to 249 in July and 492 in August.

CARP BEHAVIOR FOLLOWING DISPLACEMENT. Carp captured (primarily at MS2) in June, 1984 dispersed throughout Pymatuning Lake after spawning. Only one returned to MS2 (Table 2). None of the MS2 tagged carp migrated to the carp bowl during the remainder of the summer (Table 2). This behavior suggested that carp in the bowl might be different or from a different population than those spawning or in Middle Lake. A return by many tagged carp to MS2 following the June tagging would have reinforced a resident population theory. The results seem to indicate that no such resident population existed, at least in Middle Lake. This was reinforced by July and August observations of other local site carp (Table 2). Again no tagged local carp was recaptured at its tag release site. Carp displaced in July and August from the carp bowl returned to the bowl (Table 2). Return distances of up to 8 km were observed from as far away as MS5 (Fig. 2). July and August returns across the lake to the bowl were also noted for fish from MN4, which is 6.4 km west of the carp bowl (Fig. 1).

SIZE AND AGE OF CARP. Carp captured in June, 1984 at MS1 and MS2 averaged 288 mm SL (Fig. 2). July and August carp from the carp bowl averaged 329 and 318 mm SL, respectively (Fig. 2). Fish captured in June and July at northern shore Middle Lake stations were usually larger than those from southern shore stations (Fig. 3). Likewise fish captured at LEO were much smaller than those in Middle Lake (Fig. 3). Also, carp size decreased with increasing distances from the carp bowl (Fig. 3). The variation in the sized of carp trapped in the bowl suggested that subpopulations occupied the bowl. This was similar to the observations made in 1952.

Carp captured in June, 1984 were ages 2-6; carp captured in the Sanctuary as well as in the carp bowl in August were usually ages 10-13. Thus, a pattern emerges of older carp frequenting areas above, at, and below the Linesville Causeway carp bowl. Medium-sized carp abound in Middle Lake, and juveniles and small carp are abundant in Lower Lake. Although it is not known where very small (30-90 mm SL) carp occur, the sizes observed in 1984 suggest that they should occur in great abundance in the Lower Lake. The Lower Lake harbors few beds of aquatic vegetation and a smaller spawning population of carp. Large muskellunge (*Esox masquinongy*) that frequent the Lower Lake may also prey upon and thus control the numbers of young carp in Lower Lake.

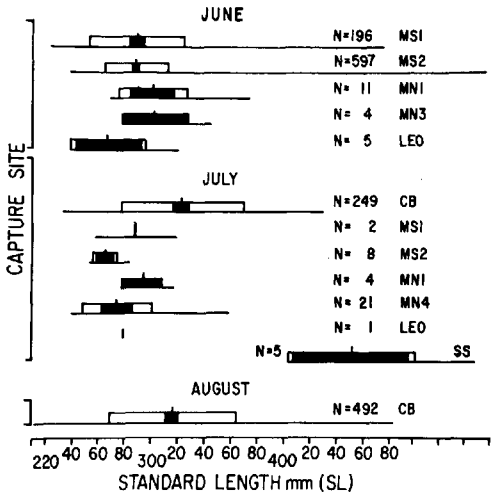

FIGURE 3. Hubbs-Hubbs diagram of carp captured and relocated, June-August, 1984. Horizontal line for each size is size range of fish; vertical line is mean ($\bar{x}$). Open bar is one standard error on each side of mean. Overlap of solid bars indicates that data are not significantly different. Non-overlap of solid lines indicates that data are significantly different between comparisons. Caution should be used in interpreting these values because of small sample sizes in some cases.

DISCUSSION

The carp is considered to be a herbivore or omnivore (Bitterman 1984; McCrimmon 1968). Feeding and fattening in this species occurs during the early summer. During the fall and winter, feeding slackens, and only occasional seeds or bottom organisms are ingested (McCrimmon 1968; Powles et al. 1983). Bread has not been reported as a component of the diet of the carp (Charles et al. 1984; Jauncey 1982; Moav and Wohlfarth 1976; Powles et al. 1983; Schwarz et al. 1985). However, it seems to be the only food available and eaten by the carp that frequent the Pymatuning Lake carp bowl.

Carp are difficult to trap (Pennsylvania Fish Commission, pers. comm.); yet a flourishing carp fishery occurs in Roosevelt Lake, Arizona, where over 100 kg are trapped monthly with the Morton Big "M" to supply a live fish market in Korea (R. Morton, pers. comm.). As a bottom feeder, the carp should be vulnerable to trapping. However, capture by trap (982 of the 1,624 tagged in 1984) in Pymatuning Lake seemed to be temperature-dependent. This was evident in July and August, when trapping success increased dramatically in response to increasing water temperatures (10°C-17°C in June; 24-25°C in July; 25-29°C in August).

EFFECTS OF TRAPPING. The Big "M" trap is similar to the Caribbean modified "Z" trap (Munro 1974; Sutherland and Harper 1983). Although factors such as mesh size, baiting vs. non-baiting, soak time, opening type and size, escapement, bait, and attraction (Munro 1974; Schwartz and Howland 1978; Wohlfarth et al. 1983) were possible influences on the number of carp captured during the 1984 study, no attempt was made to resolve just how many carp could have been caught. It was apparent that trapping success increased with rising water temperature. Likewise, the use of molasses-coated soybean and cottonseed cakes as baits may have also helped to increase trapping success. Use of bread as bait produced no trapped carp. Catches were also larger when cottonseed cake was used rather than soybean cake. Soybean cake had a tendency to disintegrate faster than the cottonseed cake. Trap captures were usually better during the morning than in the afternoon. Although the trapping interval was slightly longer prior to the morning check, carp were apparently more vulnerable to trap-

ping at night than during the day. Why this occurred remains unexplained because the water during both the 1952 and 1984 studies was always murky, with Secchi disk readings of only 0.3 m. Likewise, the major differences between the shorter recapture times noted in 1952 and 1984 were that the carp bowl was fished daily in 1952, but only for a week during each month from May-August, 1984. Hence, tagged carp could have negotiated the return distances in 1984 in shorter time intervals than the data suggest.

THEORIES REGARDING HOMING. Numerous theories attempt to explain fish homing or movement behavior. These range from acquired behavioral patterns to responses to cues such as sun orientation, geomagnetic fields, water currents, tides, effects of ground water taste, pheromones, sound, sound tone, water temperature, water currents, search behavior, schooling, food, predator-prey relationships, and many others (Leggett 1977, 1984, Stabell 1984). Most studies have emphasized rigorous laboratory or hatchery testing; few field studies, other than those of Hasler and Scholz (1983), have been conducted on wild fishes. Also, only a few studies have focused on fishes that homed by returning around a point of land or via some other than a straight-line path. Schwartz (1974) noted multiple returns of several oyster toadfish (*Opsanus tau*) that were displaced 8.9 km to Chesapeake Bay and then returned around Drum Point to Solomons, Maryland. Pflug and Pauley (1982, 1983) reported the homing of tagged smallmouth bass (*Micropterus dolomieui*) that were displaced 11 km in Lake Sammamish, California. They returned to the home site following a course adjustment around a point of land located between the release and home sites. Johnson and Hasler (1977) noted the movement of winter-congregating carp around minor points of land in Lake Mendota, Wisconsin. These abilities of carp to home are enlarged upon by the 9.5-km returns of Pymatuning Lake carp around Tuttle Point to the carp bowl and the 23-km west and southward movement from MN1 (Middle Lake) to Lower Lake observed in the present study.

RESPONSES TO OTHER SUBSTANCES. Although carp are well adapted to detect chemical or thermal stimuli (Kawamura and Tamura 1980), studies of other cyprinid and percid fishes (Asbury et al. 1981; Lebedeva et al. 1975a, b; Kasumyan and Lebedeva 1979; Smith 1976a, b, 1982, 1983) suggest that perhaps skin repellants, alarm substance, or pheromones may underly the aggregating behavior of the fish at the carp bowl. Asbury et al. (1981) provided evidence that water conditioned by red shiners (*Notropis lutrensis*) causes movement to and congregation of conspecifics in that water. Smith (1976a, b, 1982, 1983) showed that alarm substance cells in the skin may be lost or diminish in fathead minnows (*Pimephales promelas*) and other cyprinids during the spawning season. Whether the carp or fish in the carp bowl produce skin substances that act as preconditioners or attractants remains unanswered. The mucous covering the skin certainly must act as protection during the constant abrasion and agitation at the carp bowl and during spawning.

Thus, carp in Pymatuning Lake exhibit an interesting homing behavior. Visual cues, currents, sounds, sun orientation, "follow-the-leader", and schooling behavior do not explain the aggregating behavior in the carp bowl or the homing behavior to this site. Although the behavioral pattern remained the same between 1952 and 1984, the forces that guide carp to the carp bowl will remain unknown until large-scale sonic tagging and tracking experiments are performed. Studies of the movements of blind carp and carp with occluded nares should also be conducted. These and a host of other studies will unlock the secrets of a fascinating behavior exhibited by carp in Pymatuning Lake.

ACKNOWLEDGMENTS. Especial thanks are extended to the Pennsylvania Fish Commission for providing the carp used in 1952 as well as for the logistic support provided by S. Hood, J. Harvey, and N. Beaver during both the 1952 and 1984 studies. G. Anton, creel census biologist of the PFC, supplied tags recovered during daily circuits of Middle Lake in the summer of 1984. B. Janiak, Commission secretary, forwarded 1984 and 1985 recapture tags returned after the main 1984 field efforts. J. Gildea of the Institute of Marine Sciences (IMS) was an able field assistant during the 1984 study who also endured seining in May, when water temperatures were barely 10°C. O. Lewis of the IMS kept gear operative. V. and H. Page of the IMS produced the figures. Sport fishermen throughout the lakes were most enthusiastic in returning information, tags, and tagged carp. Concessionaires at the Linesville Causeway, Espyville Causeway, and at the marina west of Linesville, Pennsylvania were most helpful and cooperative. R. Morton of the Morton Trap Company, Holden Beach, North Carolina, expedited the construction of the Big "M" traps and provided information about its use and the trapping of carp elsewhere. The PFC, Ohio Division of Wildlife, and Park personnel provided operating permits and land checks for tags. Drs. R. Hartman and W. Coffman of the Pymatuning Laboratory of Ecology, University of Pittsburgh, provided constant encouragement, help with logistics, and the occasional use of their maintenance personnel to provide equipment. An opportunity to conduct the 1984 studies was provided by the G. M. McKinley Research/Pymatuning Foundation. Dr. W. Matthews, University of Oklahoma, and Dr. S. Ross, University of Southern Mississippi, reviewed the manuscript and offered suggestions for its improvement. B. Bright typed the manuscript.

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